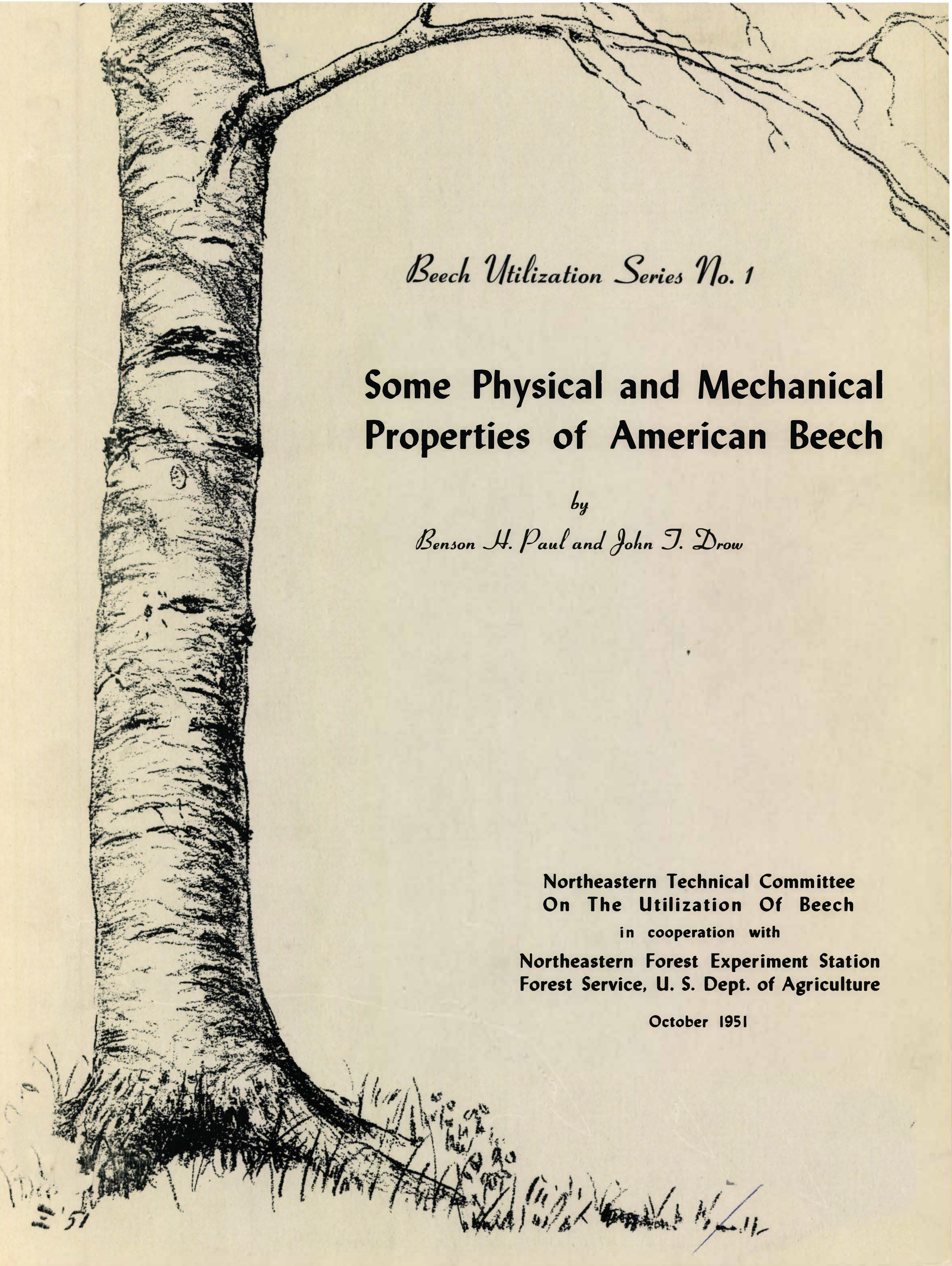

Beech Utilization Series No. 1

Some Physical and Mechanical Properties of American Beech

by

Benson H. Paul and John T. Drow

Northeastern Technical Committee On The Utilization Of Beech

in cooperation with

Northeastern Forest Experiment Station Forest Service, U. S. Dept. of Agriculture

October 1951

FOREWORD

The wood of the American beech tree (*Fagus grandifolia* Ehrh.) is well suited for a large number of uses, and it is rather widely used by manufacturers. Yet the amount used is not in proportion to the amount that grows in our northeastern forests. The utilization of beech--both in the woods and in the factory--has been recognized as a problem.

One reason for this is in the nature of the wood: it has a reputation for being difficult to season. Another is that many of the beech trees in our forests are of poor quality. And there are some plain prejudices against beech.

Research is finding ways to utilize beech as efficiently as any of the other comparable hardwoods can be handled. Considerable information about beech has been gathered. Yet most of this information is available only in fragmentary form in scattered technical reports. Some of it has never been published.

To study the problems of putting beech to the uses it deserves, and to promote the better management of the forests in which it grows, a Northeastern Technical Committee on the Utilization of Beech was organized in 1949. This committee, which includes representatives of Federal and State forestry agencies, universities, and state experiment stations, decided to assemble and publish the available information about the utilization of American beech.

As its part of this cooperative project, the Northeastern Forest Experiment Station has undertaken to edit, publish, and distribute the series of reports that will contain this information. This report on the physical and mechanical properties of beech is the first in the series.

The subjects of these reports will be as follows:

Physical and mechanical properties of American beech.

(CONTINUED ON INSIDE OF BACK COVER)

SOME PHYSICAL AND MECHANICAL PROPERTIES OF AMERICAN BEECH

by

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GENERAL CHARACTERISTICS

AMERICAN BEECH (Fagus grandifolia Ehrh.) is a common species of Northeastern hardwood forests. Its range extends from southern Quebec and Ontario, Canada, to the Gulf of Mexico. The name "American beech" distinguishes it from the European variety. In this country it is usually called simply "beech."

American beech trees are characterized by rather wide sapwood, commonly 2 to 5 inches, sometimes more. (Radial thicknesses of sapwood in 26 trees from four localities are presented in table 1.) In some trees, the heartwood is distinctly reddish in color; in others, the change from sapwood to heartwood is gradual and the heartwood is much lighter in color. This difference in heartwood color has given rise to the names "red beech" and "white beech." No botanical dif-

[1] MAINTAINED AT MADISON, WIS., IN COOPERATION WITH THE UNIVERSITY OF WISCONSIN.

ferences have been recognized between trees having red heartwood and those in which it is lighter-colored, and there is no evidence that the properties of heartwood, whether red or white, differ from those of sapwood if the wood is of comparable density. The reason for the variation in color is unknown.

American beech trees may grow slowly when in mixture with more dominant species, and because of their high degree of shade tolerance they may merely maintain themselves for many years; yet, when the stand is cut, they respond to increased growing space by quickening their growth rates. As a result of this behavior, many of the American beech trees now standing have narrow-ringed wood in the centers--sometimes 30 to 40 rings to the radial inch--followed by much wider growth rings--10 or less to the radial inch--later on. Such trees of vigorous later growth also have wider sapwood than trees that have remained under keen competition.

The wood of the American beech tree is diffuse porous; it has a fine, uniform texture somewhat similar to that of yellow birch and sugar maple.

Beech wood has numerous uses, such as furniture, flooring, brush backs, handles, agricultural implements, and many articles of woodenware and turnery. The poor-quality logs, tops, and branches make excellent fuel and can be used for pulpwood. However, beech wood is nondurable under exposed and moist conditions.

A comparison of the properties of the clear wood of beech with those of other well-known woods is made in this report by use of composite values or index numbers that are more readily understandable than technical terms used by architects or engineers. American beech is taken as 100 points. The relative position of beech in comparison with other species can be obtained from the numerical values listed in table 2, or from the bar charts (figs. 1 to 9), which show the various species in order of descending rank.

DENSITY

Tests of American beech from 21 sources in the eastern United States show that the wood is fairly uniform in density. Average differences in specific gravity between

localities are relatively small, there being greater variation in the wood of an individual stand or different parts of a tree than in the average of a group of trees from different parts of its geographic range.

The most outstanding differences are found between the wood of slowly grown old-growth trees and that of thrifty second-growth trees, particularly the narrow-ringed wood from the outer part of the old-growth trees. American beech trees that have responded to additional growing space produce heavy wood during the period of accelerated growth.

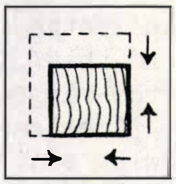
Data for American beech wood from 21 sources are given in table 3. The localities represented are in the states of Vermont, New Hampshire, New York, Pennsylvania, Michigan, Indiana, West Virginia, Alabama, Georgia, Florida, and Louisiana. Age of the trees (as far as available from the records) and average growth rate expressed as number of rings per radial inch are included. For each locality the number of trees tested, the number of tests, the average number of rings per inch, and the minimum, maximum, and average specific gravity of the wood are listed. The average specific-gravity values of wood from different sources ranged from 0.52 to 0.62. The average of individual specific-gravity specimens of wood from all sources was 0.57. The total variation of all specimens ranged between 0.43 and 0.70 in specific gravity. The distribution of variation by specific gravity classes within this range is shown by the frequency graph, figure 10.

American beech is among the heavier hardwoods of commercial importance. In a thoroughly dry condition (12 percent moisture content) it weighs, on the average, about 45 pounds per cubic foot. A comparison of the weight of air-dry beech with several other species is given in figure 1. The true hickories and the white oaks (taken as a group) are the only native hardwoods of wide commercial importance that are heavier than air-dry beech.

It is common knowledge that heavy woods are usually stronger than the lighter woods, and American beech is no exception to this general rule. It is used for many of the same things as sugar maple and yellow birch, and frequently these three woods are grouped together--for instance, in production records--as beech, birch, and maple.

SHRINKAGE

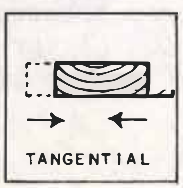
Volumetric



The wood of American beech is characterized by a rather high degree of shrinkage during drying. The amounts of shrinkage in volume have been recorded for many of the samples used for specific gravity determinations. Measurements of dimensional changes from green to oven-dry conditions were made in the tangential, radial, and longitudinal directions of the grain of the wood on specially prepared specimens.

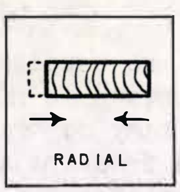
Thirty-five trees representing both old-growth and second-growth stands were included in the volumetric-shrinkage determinations. Shrinkage ranged from 14.4 to 22.3 percent of the green volume for individual specimens, and averaged 17.5 percent for a total of 324 tests (representing 6 of the 21 sources). There was a tendency for pieces having high specific gravity to shrink somewhat more than pieces of low specific gravity, as is illustrated by the graph showing the relationship of specific gravity to volumetric shrinkage (fig. 11).

Tangential And Radial



Tangential shrinkage varied from 8.6 percent to 14.9 percent and averaged 12.2 percent of the green dimension in 128 tests (representing 6 localities). Radial shrinkage usually averaged about one-half the amount of tangential shrinkage. It ranged between 4.3 and 7.5 percent of the green dimension and averaged 5.6 percent for material representing the same 6 localities as volumetric and tangential shrinkage.

The tangential- and radial-shrinkage specimens were measured at two intermediate stages of drying: i.e., when at moisture equilibrium at 65 percent relative humidity, and at 30 percent relative humidity. The average moisture content of the specimens and the amount of shrinkage at these stages of drying are given in table 4.

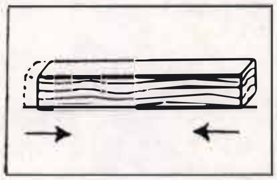


Roughly one-half to two-thirds of the total shrinkage took place in drying from the green condition to a moisture content of 12 to 13 percent,

and about three-fourths of the total shrinkage took place in drying from green condition to 6 to 7 percent.

A comparison of the shrinkage of American beech with that of other species is shown in figure 2. While the actual comparison is based on the total volumetric shrinkage from green to oven-dry condition, approximately the same relationships among species would also be expected to apply for smaller changes in moisture content.

Longitudinal



Measurements that would indicate ranges of longitudinal shrinkage were made on material from 4 out of the 10 trees represented in the shipment from Oswego County, N. Y. Three of these trees had unusually large longitudinal shrinkage. In one tree high shrinkage was found on opposite sides of the pith, but in the other two it was present only on one side of the tree.

Longitudinal shrinkage from green to oven-dry condition ranged up to 0.67 percent of the green dimension. The normal amount of shrinkage in this direction is not expected to exceed 0.30 percent in most species. Specimens with large longitudinal shrinkage were found by microscopic examination to contain tension wood. That abnormal type of wood occurs in many hardwood species and its inherently large shrinkage along the grain is a common cause of warping in beech, birch, elm, maple, hickory, oak, cottonwood, and aspen.

SPIRAL GRAIN

Like most species, some beech trees have spiral grain. An indication of the prevalence of spiral grain in beech is found in the report on machining and related characteristics of southern hardwoods,[2] in which 6.9 percent of the boards tested contained spiral grain.

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[2] DAVIS, E. M. MACHINING AND RELATED CHARACTERISTICS OF SOUTHERN HARDWOODS. U.S. DEPT. AGR. TECH. BUL. 824. 42 PP., ILLUS. 1942.

In the same series of tests, 7.0 percent of the steam-bending samples were reported as failing in "cross-grain tension." The grain had a high degree of spiral in at least one log of shipment 1648 from New York State, and it was present to a lesser degree in some of the other logs. In general, occurrence of spiral grain is not sufficiently prevalent in beech to cause a high amount of degrade. In the southern hardwood study, warping of beech in twist and cup was only slightly more than in magnolia and elm and considerably less than in gum and sycamore.

BENDING STRENGTH

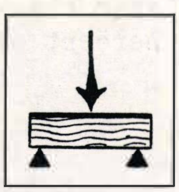
The bending strength of American beech compares favorably with that of rock elm and yellow birch, but is somewhat lower than that of ash, sugar maple, and hickory (fig. 3). For most uses of American beech, however, the bending strength is not so important as other properties and is generally more than adequate.

COMPRESSIVE STRENGTH

(Endwise)

As in the case of bending, the compressive strength of American beech is high in comparison with most species--about the same as rock elm and yellow birch, and somewhat less than sugar maple, ash, and the hickories (fig. 4). This property is not critical in most uses of American beech.

STIFFNESS



American beech is a very stiff wood; that is, it does not bend readily under load in ordinary conditions of use. Its stiffness is comparable to that of birch and maple (fig. 5). On the other hand, beech can be bent readily after steaming and, if held in clamps while drying, will retain permanently the desired curvature. This property

makes American beech an excellent wood for such uses as the curved parts of chairs.

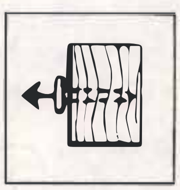
HARDNESS

The clear wood of American beech is somewhat harder than that of yellow birch, but it is not so hard, on the average, as woods of the red and white oak groups, rock elm, sugar maple, ash, and the hickories (fig. 6). The hardness and other properties of beech make it a preferred species for such uses as shuttles, spools, bobbins, looms, toys, woodenware, novelties, shoe heels, dowels, furniture, handles, and the like. American beech wears well, and it stays smooth when subjected to friction.

SHOCK RESISTANCE

In ability to resist shock, American beech is intermediate among the important hardwoods (fig. 7). Sugar maple, the red oaks, and ash are in about the same class as American beech, and these are exceeded by yellow birch, rock elm, and the hickories. Shock resistance of the clear wood of all species varies greatly with relatively small differences in specific gravity, so that within any species some pieces will have much greater resistance to shock than others. Thus, if shock resistance is of particular importance, it is desirable to use some method of selection whereby pieces of lower density can be eliminated.

NAIL-HOLDING POWER



The nail-holding power of American beech is high; but, in common with many other hardwoods, nails are hard to drive into it and have a tendency to split the wood. Various factors influence the resistance to withdrawal of nails from wood, including the species and density, changes in the moisture condition of the wood, the area of

contact between the wood and the nail, the surface condition of the nail shank, and the shape and form of the nail, including the head, shank, and point.

The relationships shown in figure 8 are for load required to pull one seven-penny cement-coated nail immediately after the nail has been driven into dry wood $1\frac{1}{4}$-inches. They would be expected to differ somewhat for other types of nails and with other conditions. The tendency to split in nailing can be reduced by the use of blunt-pointed nails, but at some sacrifice in holding power.

SPLITTING

American beech wood is rather uniform in texture, and offers considerable resistance to splitting. The data in table 2 and figure 9 are based on properties that involve the strength of wood across the grain, such as in connection with the use of bolts and wedges. These data, therefore, are not a measure of the tendency to split in nailing, which depends largely on the hardness and texture of the wood, nor of the tendency of wood to split in handling or in service.

Table 1.--American beech: Radial thickness of sapwood

Shipment No. and origin	Tree No.	Number of bolts	Average diameter of bolts	Number of sapwood measurements	Average radial thickness of sapwood
			Inches		Inches
904 Vermont	11	1	10.6	2	2.8
	12	1	11.9	2	3.1
	13	1	11.2	2	3.6
	14	1	11.5	2	3.1
	15	1	12.4	2	2.8
	16	1	13.8	2	4.0
	17	1	22.4	2	6.8
Average	--	--	13.4	--	3.7
1431 West Virginia	26	4	13.0	8	4.9
	27	4	9.2	8	3.6
	28	3	8.6	6	2.9
	29	4	10.4	8	4.6
	30	4	11.3	8	5.0
Average	--	--	10.5	--	4.2
1648 New York	1	1	20.0	2	3.5
	2	1	17.5	2	2.0
	3	1	17.7	2	3.0
	4	1	16.0	2	3.0
	5	1	15.0	2	1.5
	6	1	15.0	2	2.8
	7	1	14.2	2	2.1
	8	1	16.2	2	2.5
	9	1	15.8	2	2.2
	10	1	16.0	2	3.0
Average	--	--	16.3	--	2.6
1649 New York	5	2	12.2	4	2.6
	6	2	13.8	4	2.1
	7	2	13.4	4	2.3
	8	2	15.5	4	3.2
Average	--	--	13.7	--	2.6

Table 2.--American beech: Average mechanical and physical properties of clear wood compared with other species[1]

Species	Weight per cubic foot: Green	Weight per cubic foot: At 12 percent moisture content	Shrinkage	Bending strength	Compressive strength (endwise)	Stiffness	Hardness	Shock resistance	Nail holding power	Splitting resistance
	Lb.	Lb.	Pts.	Pts.	Pts.	Pts.	Pts.	Pts.	Pts.	Pts.
Beech, American	54	45	100	100	100	100	100	100	100	100
Ash, commercial white[2]	48	41	78	108	113	95	113	103	[3]95	[3]87
Birch, yellow	57	43	102	104	104	103	90	121	97	77
Elm, American	54	35	89	83	79	77	69	91	72	--
Elm, rock	53	44	85	104	103	88	108	140	--	--
Hickories, pecan[4]	62	45	85	118	123	98	148	153	--	--
Hickories, true[5]	63	51	112	135	131	111	--	216	--	--
Maple, red	50	38	79	91	93	94	82	82	--	--
Maple, sugar	56	44	91	112	113	105	120	102	100	--
Oaks, commercial red[6]	64	44	88	99	98	99	107	103	[7]93	[7]95
Oaks, commercial white[8]	63	47	96	97	99	88	114	93	[9]98	[9]97
Pine, eastern white	36	25	47	62	71	70	37	41	46	33
Sweetgum	50	34	93	84	82	79	63	73	--	77

[1]This table is for use in comparing the clear wood of American beech with that of other species, or for comparing beech lumber with lumber of other species containing like defects.

[2] Average of 4 species: Biltmore ash, blue ash, green ash, white ash.

[3]White ash only.

[4]Average of 4 species: Bitternut hickory, nutmeg hickory, water hickory, and pecan.

[5]Average of 4 species: Shellbark hickory, mockernut hickory, pignut hickory, and shagbark hickory.

[6]Average of 9 species: Black oak, laurel oak, pin oak, northern red oak, scarlet oak, southern red oak, swamp red oak, water oak, and willow oak.

[7]Northern red oak only.

[8]Average of 6 species: Bur oak, chestnut oak, post oak, swamp chestnut oak, swamp white oak, and white oak.

[9]White oak only.

Table 3.--American beech: Source, age, rings per inch, and specific gravity range and average of samples

Shipment and mill number	State	County or parish	Age (range)	Material tested	Number of tests	Rings per inch	Specific gravity: Oven-dry weight, green volume		
			Years			Av.	Min.	Max.	Av.
Shipment:									
[1]111	Ind.	Hendricks	235-270	5 trees	361	18	0.43	0.70	0.57
[1]197	Pa.	Potter	164-210	5 trees	91	20	.43	.58	.53
[1]904	Vt.	Bennington	[2]60-80; 150-210	7 trees	178	11	.49	.68	.59
959	Mich.	Seven locations	--	Lumber	61	--	.48	.64	.57
1358	N.H.	Lincoln	--	Bolts	40	--	.48	.66	.58
1359	N.H.	Lincoln	--	Squares	60	--	.47	.64	.59
1431	W.Va.	Randolph	60-80	4 trees	131	10	.53	.68	.61
1648	N.Y.	Oswego	175	10 trees	67	17	.57	.68	.62
1649	N.Y.	Otsego	114-206	4 trees	49	--	.55	.64	.60
2405(PP)	Pa.	Elk	--	Split pulpwood	19	18	.46	.59	.52
2758(PP)	Pa.	Elk	30-69	Pulpwood	17	16	.49	.59	.54
2934(PP)	N.Y.	Essex	41-123	Pulpwood	15	14	.50	.62	.55
Mill:									
1	Ala.	Montgomery	--	Lumber	40	11	.49	.63	.56
4	Ga.	Richmond	--	Lumber	6	11	.54	.63	.57
7	Miss.	Madison	--	Lumber	34	14	.45	.59	.54
10	Ga.	Chatham	--	Lumber	13	12	.51	.59	.55
19	La.	Caldwell	--	Lumber	41	14	.47	.64	.55
20	Fla.	Washington	--	Lumber	4	20	.48	.59	.54
21	La.	LaSalle	--	Lumber	40	14	.47	.62	.55
35	W.Va.	Wyoming	--	Lumber	20	16	.50	.59	.55
36	W.Va.	Greenbrier	--	Lumber	52	19	.40	.61	.55
					Weighted average				0.57

[1]Includes specific gravity from compression-parallel and specific gravity data.

[2]5 of the 7 trees were 60-80 years old.

Table 4.--American beech: Dimensional shrinkage (percentage of dimension when green) from green to air-dry, kiln-dry, and moisture-free condition

(In percent)

Radial: Moisture content	Radial: Shrinkage	Tangential: Moisture content	Tangential: Shrinkage	Longitudinal: Shrinkage
AIR DRY				
12.6	3.0	12.3	8.2	0.12
KILN DRY				
6.6	4.5	6.7	10.6	0.22
OVEN DRIED TO ZERO MOISTURE CONTENT[1]				
0	5.6	0	12.3	0.36

[1]Volumetric shrinkage: 17.6 percent.

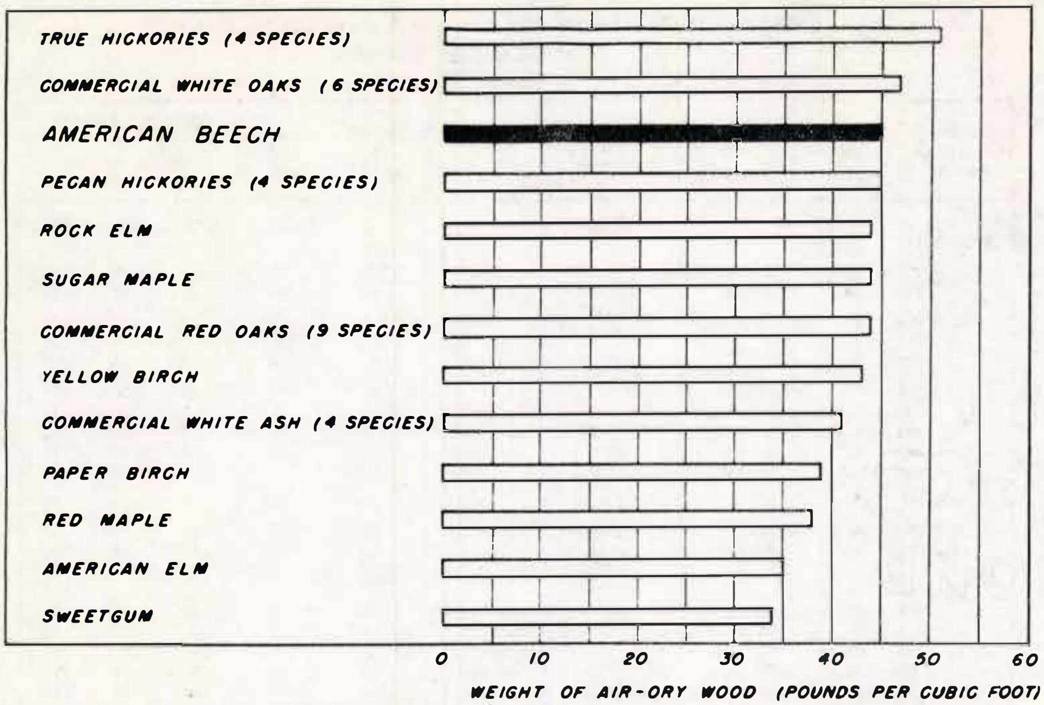


Figure 1.--Weight of air-dry American beech (12 percent moisture content) compared with weight of several other species.

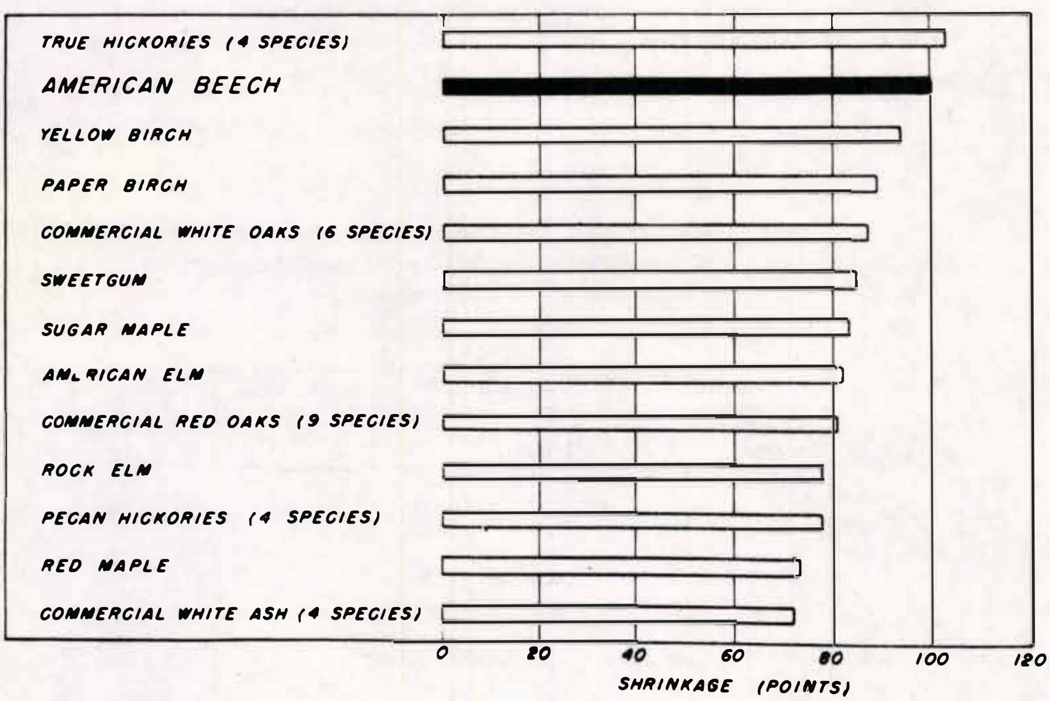


Figure 2.--Average volumetric shrinkage of American beech compared with that of several other species.

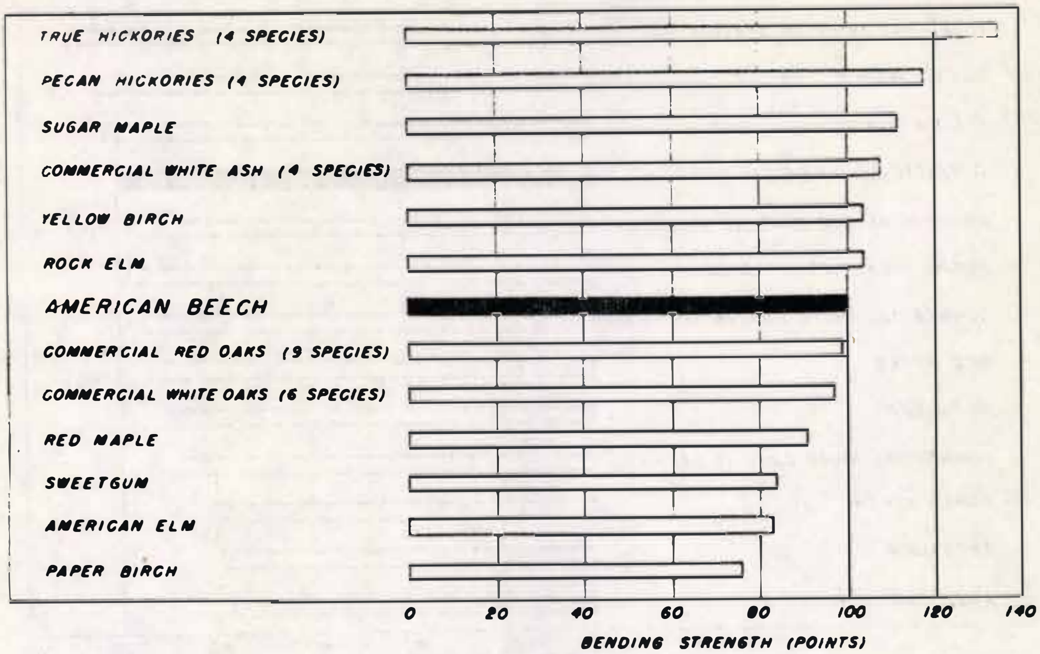


Figure 3.--Average bending strength of the clear wood of American beech compared with that of several other species.

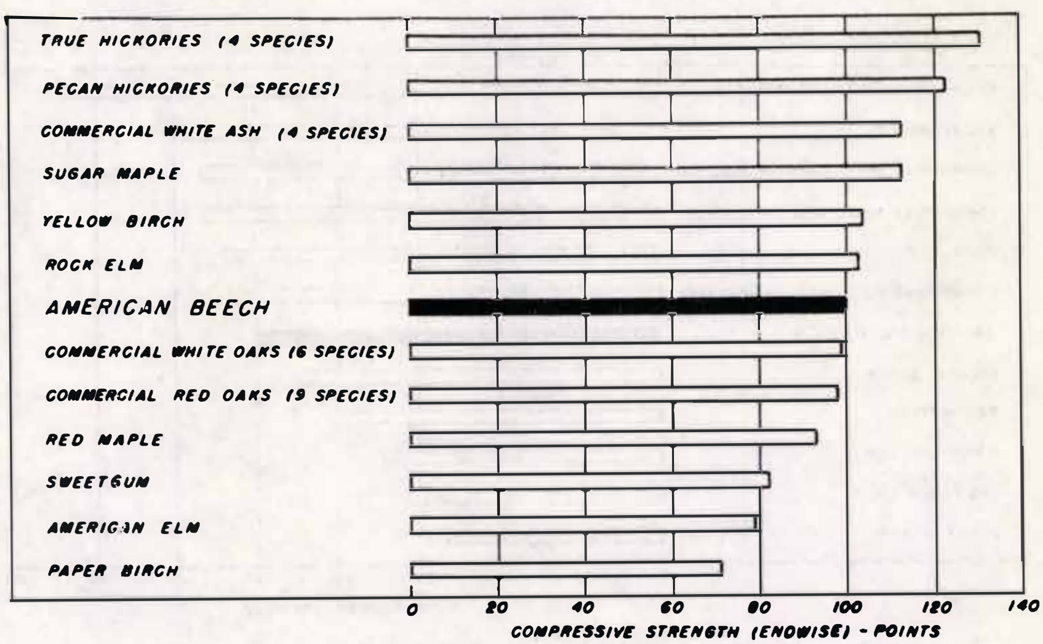


Figure 4.--Average compressive strength (endwise) of American beech compared with several other species.

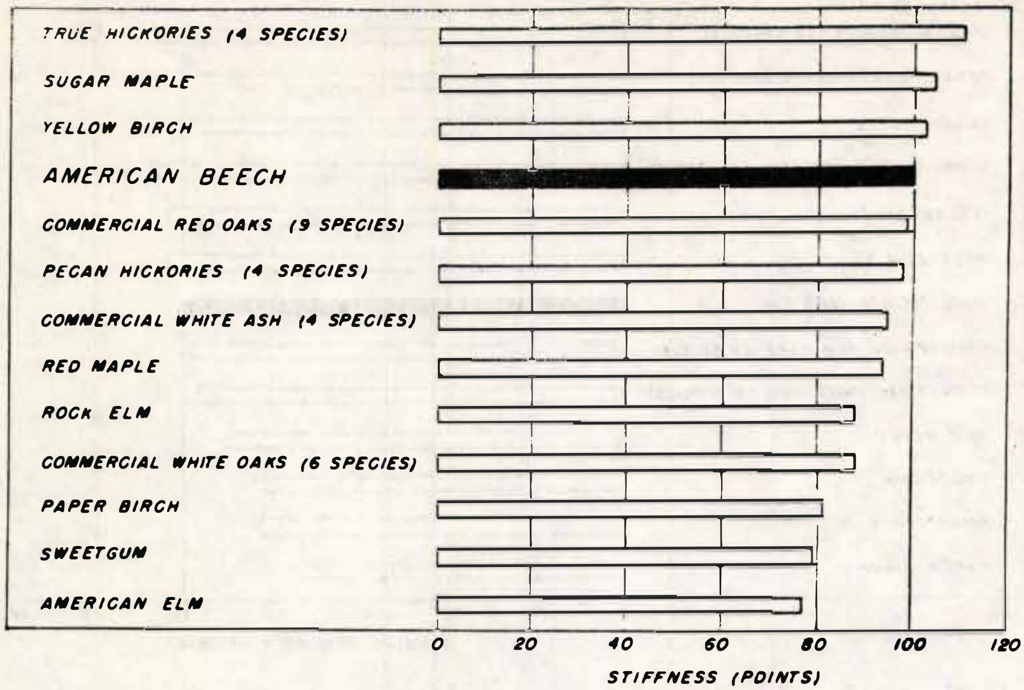


Figure 5.--Average stiffness of the clear wood of American beech compared with that of several other species.

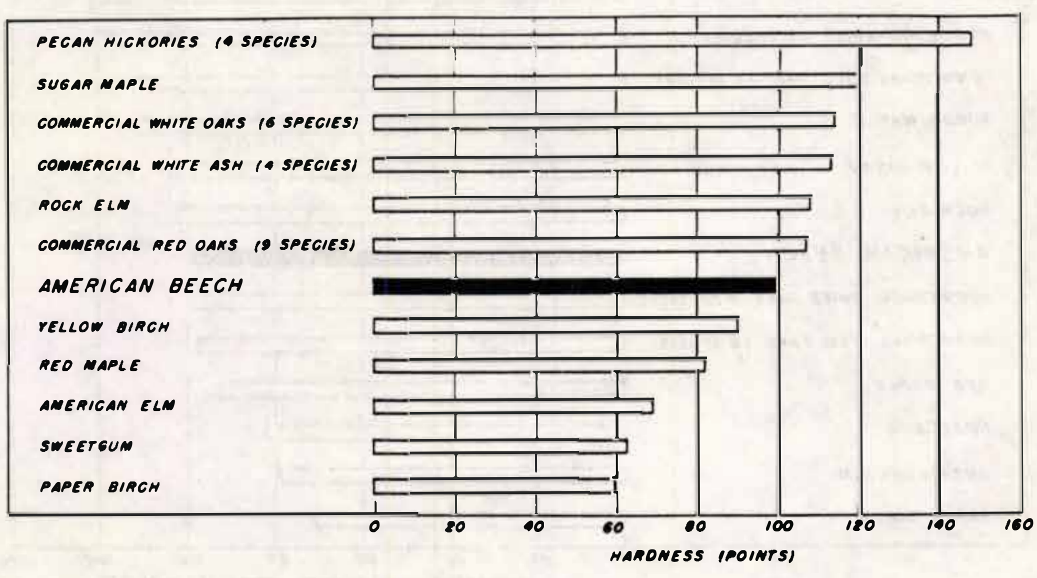


Figure 6.--Average hardness of the clear wood of American beech compared with that of several other species.

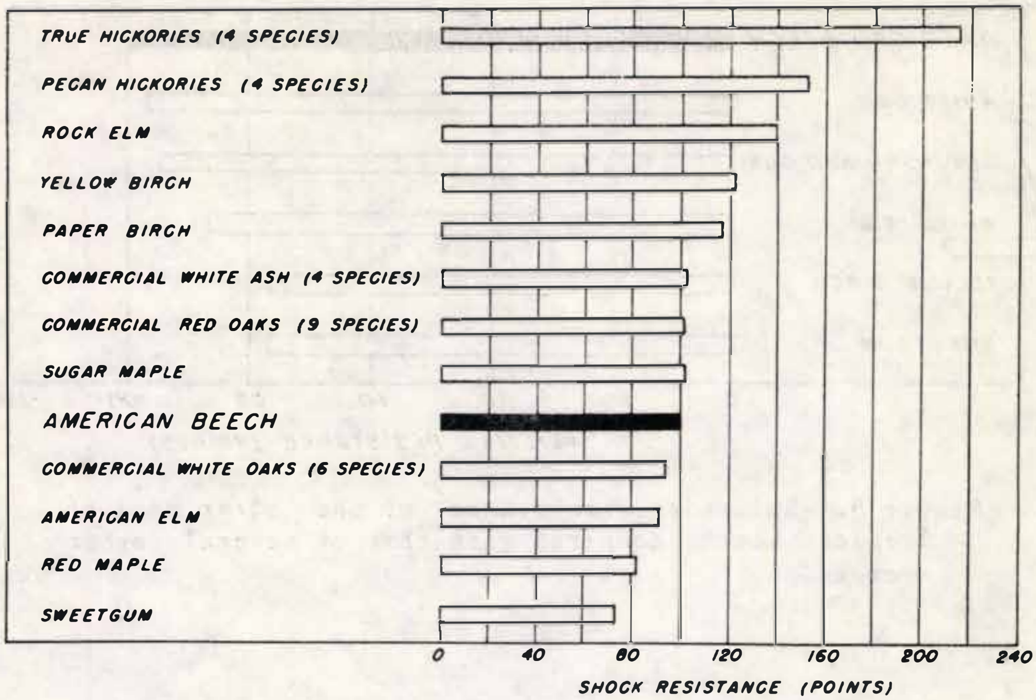


Figure 7.--Average shock resistance of the clear wood of American beech compared with that of several other species.

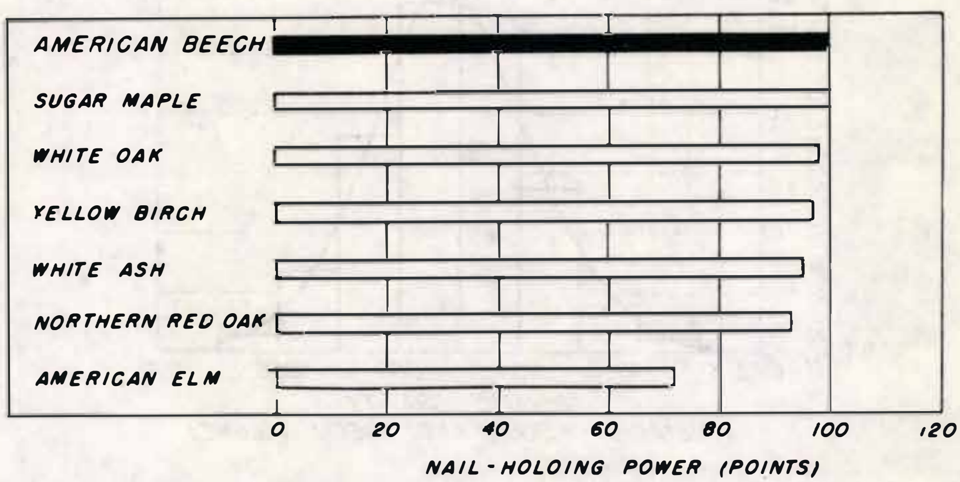


Figure 8.--Nail-holding power of American beech compared with that of several other species.

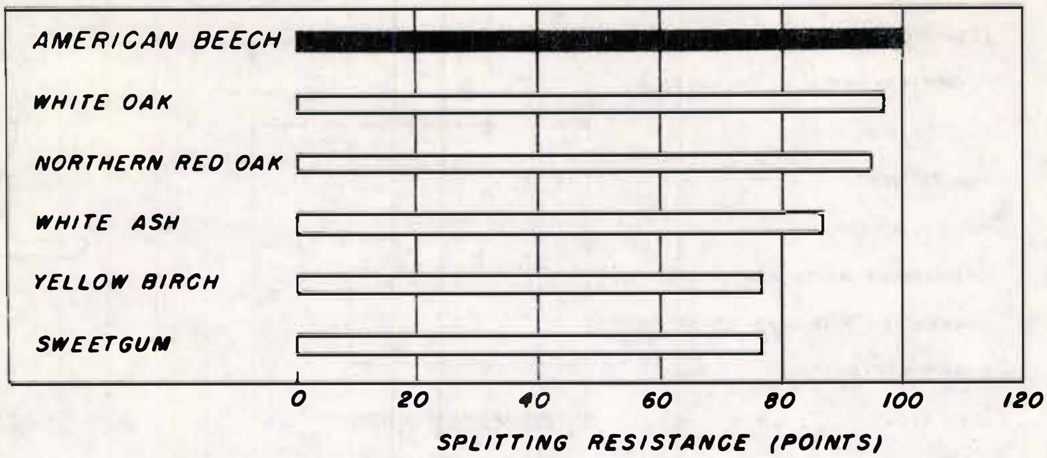


Figure 9.--Splitting resistance of the clear wood of American beech compared with that of several other species.

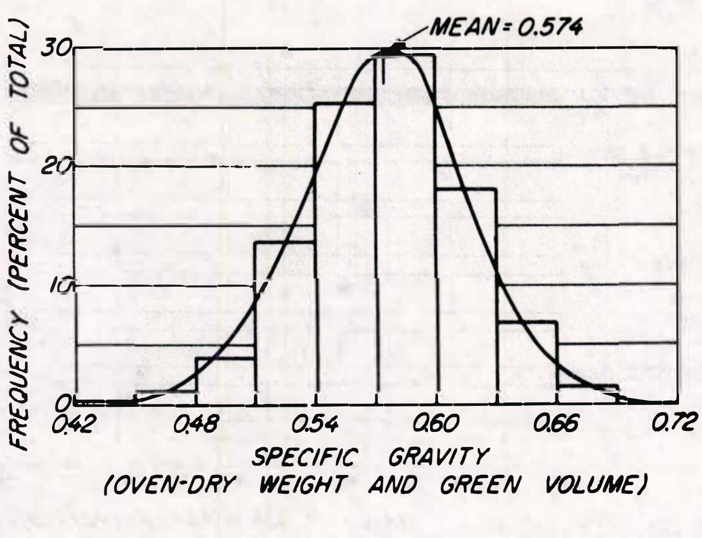


Figure 10.--The frequency in specific-gravity variability of 1,337 specimens of American beech of all heights from 21 sources in the United States.

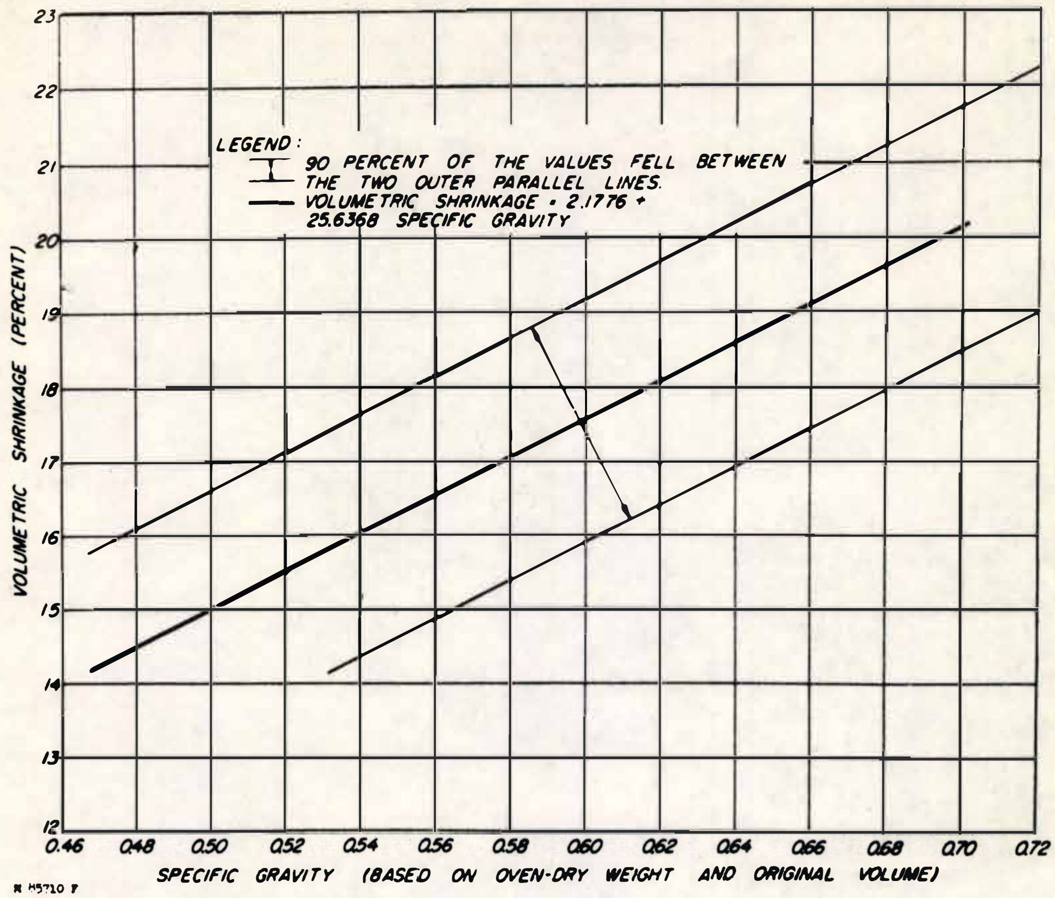


Figure 11.--Shrinkage in volume of American beech in relation to specific gravity of the wood.

(CONTINUED FROM INSIDE OF FRONT COVER)

Chemistry and chemical utilization of beech.
Management of beech.
Beech availability and supply.
Present markets and uses for beech.
Methods of logging beech.
Seasoning of beech.
Storage of beech logs and bolts.
Machining of beech.
Milling of beech.
Gluing of beech.
Bending of beech.
Preservative treatment of beech.
Beech for flooring.
Beech for furniture.
Beech for turned products and novelties.
Beech for veneer and plywood.
Beech for fuel and charcoal.
Beech for cross ties.
Beech for containers.
Pulping and defiberization of beech.
Rough construction on the farm with beech.

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The information gathered in this widespread cooperative project should be of great use to the wood-using industries of the regions where the wood of American beech is available.

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